REVIEW OF THE VALUE OF SALT AS A FERTILISER AND HERBICIDE FOR VEGETABLES

Horticulture Development Council

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CONTENTS

CONTENTS

1. ABSTRACT

1.1 The purpose of this review is to examine the evidence for the use of salt as a fertiliser and extending its use to a wider range of vegetable crops. Its use as a herbicide is also considered.

1.2 The value of salt as a fertiliser has been established for some centuries.

1.3 Sodium is only essential for some *Atriplex* species. Other plants can grow and reproduce without it. Chlorine is essential but only in small amounts.

1.4 The natural input from rainfall is about 8 kg/ha sodium and 20 kg/ha chlorine per annum in inland sites in England.

1.5 The role of sodium in plants is to substitute for potassium. The extent to which sodium can do this varies from species to species. Some with a high uptake potential for sodium, show a positive benefit from the application of sodium. The function of chlorine is still obscure.

Both sodium and chlorine contribute to the ions maintaining the turgor pressure in the plant and can replace other ions in this role.

1.6 Sodium requirement is partly but not entirely related to the botanical similarities. Plants with a high sodium uptake potential are all *Chenopodiaceae*.

1.7 Sugar beet is the crop for which salt is most commonly used. Many field trials with salt have been carried out on sugar beet. Sodium is probably a more important nutrient for sugar beet than potassium. Other Beta species respond to sodium in much the same way as sugar beet but the evidence is least satisfactory for beetroot.

The other Chenopodiaceae grown as vegetables also seem to be responsive to sodium. Some Brassicae respond to sodium, particularly cabbage, kale and turnips. Extensive trials on carrots have shown a consistent response to salt. Celery is known to respond, but there is little information for parsnips.

Potatoes may respond to sodium but chloride depresses yields and starch content. Legumes seem unresponsive to sodium. There is little information on Cucurbitaceae. Lettuce appears unresponsive to sodium, though chloride may increase yields and reduce nitrate content.

Onions are probably unresponsive to sodium as is maize.

1.8 Salt may not be required on some soils where sodium levels are high. This includes soils near the coast and peaty soils.

1.9 There is good evidence for the existing recommendations for the use of salt on carrots but less evidence for the use on celery.

1.10 Experimental evidence and botanical similarity indicate that beetroot, spinach, cabbage, kale and turnips are likely to benefit from salt. There are some important crops which may respond to salt for which there is little information.

1.11 The net benefit for using salt on carrots and celery is calculated at £295 and £1411 per hectare respectively.

1.12 The possible benefits on other crops were calculated assuming a 5% increase in yield. They range from £70/hectare for beetroot to £301/hectare for cabbage. The total UK benefit is estimated at £3M for carrots and celery and another £5M for the additional crops.

1.13 Soil applied salt has been found to improve the eating quality of carrots, turnips and celery. It may also reduce nitrate levels in lettuce and spinach.

1.14 Alternatives to salt include sylvinite, kainit and nitrate of soda.

1.15 An adverse effect of salt is a possibility of damage unless applications are well incorporated into the soil.

1.16 Salt can be used as a herbicide as the chloride content has a more toxic effect on some crops than others. Suitable rates as a herbicide range from 100 kg/ha on sandy soils to 165 kg/ha on silty clays.

1.17 The crops least affected by salt are those most likely to benefit from its use as a fertiliser so there is some scope for using it as a fertiliser and herbicide on the same crops. The rates required are different so two applications would be needed.

1.18 Salt is currently used in 54% of sugar beet fields and on about 1% of early potato, brussels sprouts, kale, swedes and onions, and on 7% of cabbage fields.

1.19 Future research and development (R & D) should include some detailed field trials on a range of crops and some simple field trials on a range of growers holdings. Quality benefits as well as yield benefits should be measured.

A databank of fertiliser recommendations for vegetables from other temperate countries would be extremely valuable as a source of information and to prevent duplication of R & D.

Other R & D required is a survey on the use of salt and trials on salt as a herbicide.

2. INTRODUCTION

The value of salt as a fertiliser for some crops is widely accepted throughout the world. Yet the use in Britain is largely restricted to sugar beet. The purpose of the review is to examine the evidence for the value of salt as a fertiliser for vegetable crops. Firstly for those for which it is currently recommended, and then to consider the likely benefits of extending the use of salt to crops for which it is not currently recommended both on the basis of experimental work and on botanical similarities.

Salt also has a potential use as a herbicide and the possibilities of this use can be assessed from information on the tolerance of crops to salt. There may be beneficial interactions between the use of salt as a fertiliser and as a herbicide. Salt is also known to have adverse effects on soil structure and the likelihood of soil damage needs examining when it is used as a fertiliser.

Finally, the review of all the available evidence will highlight those areas where further R & D is required.

3. HISTORICAL USE OF SALT AS A FERTILISER AND HERBICIDE

The historical use of salt is reviewed in an article by Selman (1938) in which he states:

"The value of salt to agriculture was probably first recognized by the ancient Persians and Chinese, who are reported to have used it, especially for date trees. In large quantities it was certainly known to exert a very harmful effect on vegetation; thus the ancient Jews strewed salt on their enemies' fields to render them barren and infertile. About the time of Christ, salt was used as a manure in Italy, and Pliny (23-79 A.D.) records "that cattle have an avidity for a salt pasture, and that cows give more milk, that the milk is much more pleasant for curding into cheese than upon ground not of a saline nature."

In England, the use of salt for fertilizing certain crops has been appreciated and practised since the time of Lord Bacon, (1561-1626) who mentioned its use in his writings. With the growth of agricultural chemistry during the nineteenth century, many experiments were carried out with the object of obtaining more precise information as to the mode of action of salt, and the practical and economic benefits to be derived from its application".

It is also evident from Selman's article the reason for the beneficial effect of salt was subject to experiment. Dana (1851) is quoted as saying "It may be established as the seventh principle of Agricultural Chemistry. ONE BASE MAY BE SUBSTITUTED FOR ANOTHER IN AN EQUAL PROPORTION".

Ville (1879) took a different view:

"From a chemical point of view the closest resemblance exists between potash and soda. In nearly all the natural compounds which contain potash, soda also is found, and in order to distinguish between the two alkalines, a close acquaintance with the intricacies of chemical reactions is necessary. But to the plant there is a vast difference, for in the experiment in which potash was suppressed and where vegetation suffered so much, the soil was largely provided with soda. It is then an acknowledged fact that soda cannot supply the place of potash".

Selman (1938) summarises the current state of knowledge on the use of salt as follows:

Useful.

(1) The sodium ion has been demonstrated to be a useful, though not always essential, plant nutrient. The response of plants that are tolerant to salt (mangels, oats, sugar beet, asparagus, etc.) may be expected to be controlled by the levels of the other plant nutrients (lime, phosphate, potash, etc.) in the soil.

(2) At Rothamsted, sodium chloride has been found to be slightly superior to potassium chloride for sugar-beet, an increase of 0.29 ton of roots per acre being recorded as the average of 9 experiments. It is not yet certain whether this result is in part due to the effect of the salt on the soil, or whether it is entirely due to the action of salt in the metabolism of the plant.

(3) In dry seasons there is some evidence to show that sodium chloride increases the drought-resisting properties of the leaves.

Disadvantages.

(1) Chlorides exert a harmful effect on the yield and quality of potatoes.

(2) High concentrations of chlorides exert a deleterious effect on vegetation and may even be useful as weed killers.

4. PLANT REQUIREMENTS FOR SODIUM AND CHLORIDE

For many years since 1938 there has been discussion and experiments on whether sodium is an essential plant nutrient. Sodium is now considered only to be essential for the salt bush *Atriplex vesicaria* and other *Atriplex* species. It was not found to be essential for tomato, cabbage or lettuce (Brownell, 1968). The definition of "essential" is that the plant cannot complete the vegetative or reproductive stage of its life cycle without the element in question, and only the element can correct the deficiency, and that the element has a specific plant nutrition function.

Sodium is not essential. Any effects on crop growth and yield are due to some indirect action in the plant or through the soil.

Chlorine is an essential element but only in quantities slightly greater than is typical of trace elements. Eaton (1966) quotes estimates that plants in general require 1 pound chloride for each 4000 pounds of dry matter produced. This equates to 0.025% Cl (250 ppm) or 0.25 kg chloride per tonne of dry matter. A large crop (10 tonne dry matter/hectare) would need 6 kg/ha of chlorine.

5. NATURAL INPUTS OF SODIUM AND CHLORINE

Wadsworth & Webber (1980) measured the deposition of soluble sodium and chloride in rainfall at 6 centres in England and Wales. Sodium deposition ranged form 6.8 kg/ha/annum at Stratford to 71.9 kg/ha/annum at Lymington. The average for the 3 sites well inland was 8.1 kg/ha/annum. Chloride deposition ranged from 15.9 kg/ha/annum at Stratford to 141.1 kg/ha/annum at Lymington. The average for the three inland sites was 20.1 kg/ha/annum.

Cawse (1977) estimated the total deposition of soluble (i.e. in rainfall) and insoluble sodium and chloride from the atmosphere at seven sites in the United Kingdom. Sodium deposition ranged from 13.3 to 410 kg/ha/year and chloride from 21 to 720 kg/ha/year. Three sites were in Wales or Cumbria and the site with the very high deposition in the Shetland Isles. The three sites in the midlands and eastern England averaged 20.8 kg/ha/year and 27.2 kg/ha/year respectively for sodium deposition. These estimates are higher than those of Wadsworth & Webber (1980) as expected but both show the deposition of appreciable amounts of sodium and chloride.

No crop growing outdoors in the UK is likely to be deficient in chloride.

Chloride is also supplied in fairly large amounts to most crops as potassium chloride fertiliser.

6. ROLE OF SODIUM AND CHLORINE IN PLANTS

The previous evidence shows that sodium is not an essential element for plants and the small requirement for chlorine is naturally met by natural deposition. Thus, good yields of crops can be obtained without the application of sodium or chlorine. The beneficial effects of salt found over the centuries by practical experiment must therefore come from the action of sodium or chlorine as an additional beneficial element to the plant or as a substitute for other elements. Much of the experimental work has been to examine whether sodium has a unique effect on yields or merely substitutes for potassium when that nutrient is limiting. The role of sodium appears to vary from species to species. Chlorine may also substitute for other ions such as nitrate and malate.

6.1 Role of Sodium in Plants

The role of sodium is closely tied to that of potassium (Mengel & Kirkby, 1982, p. 425). As similar elements there are situations in which sodium can substitute for potassium.

Potassium is very mobile in the plant and is often redistributed from older plant organs to younger tissue (Hewitt, 1983). The reason for this movement is postulated as potassium having a role in protein synthesis, and the supply of cytokinins. Potassium also functions as an activator of enzyme systems. Only low concentrations of potassium are required for this function. Other cations may substitute for some of these functions, but inefficiently.

Greater amounts of potassium are required in its role as the major cation contributing to the osmotic pressure within plant cells and in the phloem sap. The osmotic pressure is necessary to maintain turgor and to allow the plant to take in water. In cells, potassium is balanced by anions, partly by nitrate, chloride and phosphate, but more so by organic anions - malate in particular. Malate, together with potassium is also a major component of the phloem sap which acts as a nutrient transport system within the plant.

As a similar cation, sodium can partially replace potassium in maintaining turgor and in the phloem. The uptake of cations by plant roots is more or less a non specific process (Mengel & Kirkby, 1982, p. 131). It has frequently been observed that the total sum of cations in a plant or plant tissue is little changed despite variations in the levels of the individual cations in the nutrient medium.

This relationship is shown in Table 1 from an experiment of Forster & Mengel (1969) in which barley plants were grown in a complete nutrient solution. In one treatment, K+ was withheld from the nutrient solution for 8 days during the growth period. After this time the cation contents of roots and shoots were determined in samples of both treatments (control and interrupted supply). As shown in Table 1, this interruption in K supply resulted in a drastic drop in the K

Table 1. The effect of an interruption in the K supply on the cation content of young barley plants; interruption period 8 days (Forster & Mengel [1969])

	Roots		Shoots	
	Control	Interr.	Control	Interr.
	milliequivalents/100 g DM			
K................................	157	28	170	152
Ca................................	9	12	24	66
Mg................................	36	74	54	21
Na................................	3	78	trace	12
Total................................	205	192	248	251

Grain yield (g/pot): Control 108
Interr. 86***

levels in the roots and shoots, whereas the contents of Ca, Mg and Na increased considerably. The total content of the 4 cation species was not significantly affected by the K interruption. This indicates that the deficient equivalents of K+ were more or less made up by the other cation species. These cations, however, were not able to substitute for the physiological functions of potassium. The yield data in the table show that the interruption in potassium supply resulted in a highly significant depression in grain yield.

The enzyme activation functions are much more specific to potassium. Sodium and potassium although similar are not identical and sodium cannot replace potassium entirely, even in the role of the cation maintaining turgor.

Mild potassium deficiency does not result in visible symptoms; at first there is only a reduction in growth rate (Mengel & Kirkby, 1982, p. 426). Due to a decrease in turgor under water stress plants easily become flaccid. Resistance to drought is decreased and affected plants show increased susceptibility to frost damage, and fungal attack.

The beneficial effects of sodium as a substitute for or in addition to potassium are also likely to show in the same way; that is as increases in yield, and resistance to disease, frost damage and drought. Plants with a high turgor pressure also tend to contain more water, which may affect their quality.

The extent to which sodium can substitute for potassium depends much on the uptake potential for sodium. This is a measure of how much sodium a plant can take up when given ample supplies of sodium and normal supplies of all other nutrients. This differs considerably between plant species (Marschner, 1971). Table 2 shows the sodium uptake potential of various crops. For the 'high' and 'medium sodium species', the favourable effect of sodium is important on plant growth.

This is particularly the case for the Beta species (El-Sheikh & Ulrich, 1970). In these species, sodium ions contribute to the osmotic potential of the cell and thus have a positive effect on the water regime of plants.

Table 2. Uptake potential of various crops for sodium (data from Marschner, 1971)

High	Medium	Low	Very low
Fodder beet	Cabbage	Barley	Buckwheat
Sugar beet	Coconut	Flax	Maize
Mangold	Cotton	Millet	Rye
Spinach	Lupins	Rape	Soya
Swiss chard	Oats	Wheat	Swede
Table beet	Potato		
	Rubber		
	Turnips		

6.2 Role of Chlorine in Plants

The function of chlorine in plants is still obscure. A number of workers have shown that in isolated chloroplasts chloride is an essential cofactor in photosynthesis. Chloride may also act as a counter-ion to potassium in aiding the rapid movement of potassium within the plant. Chloride contributes to turgor and in this respect can replace nitrate, or act in place of malate (Mengel & Kirkby, 1982, p. 546).

In the uptake of anions by roots there is some antagonism between nitrate and chloride. High chloride supply in the rooting medium lowers the nitrate uptake and vice versa. The effects are particularly marked in plants which accumulate nitrate and chloride such as the Chenopodiaceae (Mengel & Kirkby, 1982, p. 133).

Chloride application to vegetables is usually adequately supplied by rainfall and by potassium chloride fertilisers. If potassium chloride is not used there may be occasions when an application of chloride may have beneficial effects through its effect on turgor or on replacing nitrate.

7. BOTANICAL SIMILARITIES BETWEEN CROP PLANTS

Physiological similarities between crop plants are partly, but not entirely, related to their botanical classification.

The classification of the common vegetable crops and related agricultural crops is as follows:

<u>Monocotyledons</u>

Liliaceae - Asparagus
- Alliums - Leeks, Onions

Maydeae - Maize, Sweetcorn

Gramineae - Wheat, Barley, Oats

<u>Dicotyledons</u>

Cruciferae - Brassica - Cabbage, Swede, Turnip, Kale, Cauliflower, Brussels sprouts
- Raphanus - Radish

Chenopodiaceae - Beta - Beetroot, Sugar beet, Mangels
- Spinacia - Spinach

Umbelliferae - Daucus - Carrot
- Pastinaca - Parsnip
- Apium - Celery
- Petroselinum - Parsley

Solanaceae	- Solanum	- Potato
	- Lycopersicum	- Tomato
Leguminosae	- Vicia	- Broad bean
	- Pisum	- Pea
	- Phaseolus	- Runner beans, French bean
Cucurbitaceae	- Cucurbitae	- Marrow, Courgette, Squash
Compositae	- Liguliflorae	- Chicory, Lettuce

The value of the botanical classification is shown by reference to Table 2; all the crops with a high potential for sodium uptake are Chenopodiaceae. The shortcomings of the botanical classification are also shown by the same table, three brassica crops, turnips, rape and swede being classified as medium, low and very low in potential for sodium uptake.

8. EXPERIMENTAL EVIDENCE FOR THE USE OF SALT OR SODIUM AS A FERTILISER

Most of the work has evaluated the use of salt as a sodium source which has long been considered the most important nutrient in salt. Chloride is supplied by other fertilisers. Because of the worldwide importance of sugar beet more experiments have been done with this crop than any other.

8.1 Sugar beet

Although sugar beet is not a field vegetable it is worth examining the use of salt on this crop as it is the crop in which salt is most widely used and it is closely related to some vegetables. To a limited extent evidence for sugar beet may be extrapolated to other crops.

Dundas (1962) reviewed the use of sodium for sugar beet. He concludes on the basis of many trials that sodium is a more important nutrient than potassium. This is based on the evidence that applied alone sodium increases yields rather more than potassium. Sodium applied in addition to potassium increased yields but potassium applied in addition to sodium had only a small affect on yields. The data from 190 trials gave the following information.

Increase in sugar yield (kg/ha):

Potassium (150 kg/ha K_2O)	277 kg/ha sugar
Sodium (240 kg/ha Na)	240 kg/ha "
Potassium and Sodium	500 kg/ha "

Dundas (1962) gives the average sodium requirement of sugar beet as 150 kg/ha sodium applied as 375 kg/ha salt but preferably as 560 kg/ha sodium nitrate.

Tinker (1965) reported the results of 42 sugar beet trials. He concluded that 3 to 4 cwt/acre salt was worthwhile in addition to potassium. Salt had a greater benefit on sugar yield than potassium chloride and where salt was applied potassium had only a marginal effect on yields. This supports the conclusion of Adams (1959) that sodium is a more important nutrient for sugar beet than potassium.

Draycott et al., (1970) reported the results of three trials on light chalky soils. On these soils potassium was more effective than sodium and the optimum combination was about 125 kg/ha sodium and 275 kg/ha potassium. Tinker (1970) gave the results of 18 trials on peaty soils; responses to fertiliser were less than on mineral soils and salt gave only 1% increase in yield.

8.2 Other Beta Species

Fodder beet and mangels respond to sodium in much the same way as sugar beet (Hunter, 1968b) and salt is usually recommended for all three crops.

Beetroot is the same species as sugar beet, and although not quite so closely related as fodder beet and mangels it might also be expected to be responsive to sodium. Various early studies in the USA sometimes gave conflicting results (Dundas, 1964a). In some trials sodium increased beetroot yields at high levels of potassium and sometimes it did not. Field trials indicated that salt at around 50 lb/acre could increase yield by 40% even in the presence of adequate potassium fertiliser (Truog et al., 1953). More recent trials by Mercik et al., (1976) in Poland have also confirmed that sodium increases the yield of beetroot but mainly at lower potassium levels.

The effect of sodium has been measured by comparing sodium nitrate as a fertiliser with calcium or ammonium nitrate. Six beetroot trials in France showed sodium nitrate to be distinctly superior in the absence of potassium but inferior at the highest level of potassium (Dundas 1964a). Similar beetroot trials in The Netherlands, Sweden, and the USA all demonstrated sodium nitrate gave higher yields than calcium nitrate even when applied with normal rates of potassium fertiliser.

Cleaver & Bray (1966) examined the effect of sodium sulphate and borax on beetroot. No yield improvement was found from either material. Sodium sulphate had an adverse effect on the soil structure.

These trials indicate that sodium is an important nutrient for beetroot and that sometimes, it may increase yield in the presence of adequate potassium.

8.3 Other Chenopodiaceae

These include the vegetables; spinach, spinach beet and Swiss chard. Lehr (1949) carried out pot trials with spinach comparing sodium nitrate and calcium nitrate at three levels of potassium fertiliser. Sodium nitrate gave much larger yields even at high potassium levels. Dundas (1964b) reviewed the requirement of spinach for sodium. The assembled data from trials in Italy, Germany and the USA indicate that sodium nitrate is often superior to other nitrogenous fertilisers; this superiority is attributed to the sodium content. Wehrmann & Hahndel (1984, 1985) examined the effect of chloride on the yield and nitrate content of spinach. Chloride increased the yield up to a high level (350 kg/ha chloride). At the same time the nitrate content was reduced.

8.4 Brassicae

The value of sodium as a plant nutrient has been tested on several Brassica species.

8.4.1 Cabbage

The requirement of leaf brassicas for sodium was reviewed by Dundas (1965). Cabbage trials in Michigan gave yield increases of 2% to 11% from the application of sodium in the presence of potassium.

Trials in Holland with sodium nitrate gave yield increases of 11 to 28% for cabbage compared to calcium nitrate at a range of potassium levels. Similar trials in England gave yield increases averaging 10%, although sodium nitrate was similar in effect to potassium nitrate containing some sodium (Nicholson & Hooper, 1957). For cabbage the evidence is that sodium can improve yields even in the presence of adequate potassium.

Hemingway (1960b) carried out 6 trials on kale. Salt alone increased yields almost as much as potassium and, even in conjunction with the highest potassium levels, increased yields by 7%.

Costigan & Mead (1987) measured the critical potassium concentration in plants for cabbage seedlings in the presence and absence of sodium. Without sodium in the nutrient solution, the critical level was 2.2% K and with sodium it was zero, indicating that sodium can replace potassium in cabbage for almost all its functions .

8.4.2 Turnip

Holt & Volk (1945) reported pot experiments on a range of crops including turnip. Salt increased the yield of turnip by 132% in the absence of potassium fertiliser and by 3% at the highest rate of potassium (144 lb/acre K_2O). Hemingway (1960a) carried out 4 field trials in Scotland. Salt increased turnip yields more than potassium chloride and the increase was 10% at the higher level of potassium.

Lehr (1951) compared sodium nitrate and calcium nitrate as fertilisers for turnips at a range of potassium levels. Sodium nitrate increased root yields over calcium nitrate by 67% where no potassium was applied and by 14% where 100 kg/ha potassium chloride was applied.

These results indicate a moderate response to sodium even where normal rates of potassium are applied.

8.4.3 Swedes

Truog et al., (1953) carried out trials with swede in sand culture. Sodium gave large increases in yield of roots in the absence of potassium and a 14% yield increase at the highest level of potassium. They noted that sodium greatly improved the taste of the swedes, giving a mild sweet taste instead of a strong bitter taste where only potassium fertiliser was applied. Although Marschner (1971) classifies swede as having low sodium requirements, this result and the close similarity of swedes to turnips would indicate that swedes may well respond to salt.

8.5 Umbelliferae

Common vegetables in this family are Carrots, Parsnips and Celery. Carrots have been the subject of many experiments with sodium.

8.5.1 Carrots

Harmer and Benne (1945) obtained small responses to salt applied to carrots and parsnips contrasting with the larger responses given by sugar beet, table beet and swiss chard.

For carrots Truog *et al*., (1953) obtained a large response to sodium at low potassium but little increase at high potassium. Hunter (1968a) quotes results from Germany where sodium gave yield increases of 44% at low potassium and 14% at high potassium. Also quoted are English trials where salt increased carrot yields by 4% where potassium was also applied. The most recent trials in England are described by Harrod *et al*., (1974). Out of nine trials on sandy soils salt increased yields in 8 trials; the average increase was 9% at a potassium fertiliser level of 75 kg/ha, this was smaller than the increase where no potassium was applied (15.5%).

Salt at 377 kg/ha gave a higher yield than the higher rate of potassium (150 kg/ha K_2O). The substantial response to salt occurred irrespective of the potassium level in the soil. Harrod (1974) also carried out 4 trials with carrots on fen peat soils. Where no potassium was applied, salt decreased yields by 9% but at 75 kg/ha of applied potash salt increased yields by 4%.

Truog et al., (1953) noted sweeter flavour of carrots from plots where sodium was applied was sweeter.

The experiments on carrots show that at normal potassium levels there is frequently a moderate increase in yield from applying salt.

8.5.2 Celery

Harmer & Benne (1945) quote some of the earliest work on celery in the USA, and the observation that celery grown on organic soils is improved if salt is used or sodium nitrate is used as the nitrogen fertiliser. They also noted that celery receiving salt was crisper and kept in better condition when exposed in the market. Dundas (1964c) quotes more details of the trials in the USA where salt increased celery yields in the range of 17 to 36% in Michigan and 27 to 61% at East Lansing. Truog et al., (1953) found large responses to sodium (55% increase in yield) even at high potassium levels. They also note that sodium reduces excessively strong flavour and makes the stalks crisper and less stringy. Dundas (1964c) also refers to experiments with nitrogen fertilisers where sodium nitrate gave greater yields than other nitrate fertilisers.

Marks (1990) tested the use of salt for celery grown as a glasshouse crop. The soil received normal levels of potassium fertiliser; salt increased yields by 6%. The optimum rate of salt was 400 kg/ha.

8.5.3 Parsnip

Harmer & Benne (1945) included parsnips in their trials. Parsnips had a similar sodium requirement to carrots and less than that of sugar beet or beetroot. Yield increases from salt were small for both crops.

8.6 Solanaceae

This family of plants is known to have a high demand for potassium and tends to have a low uptake of sodium. Nevertheless Lehr (1953) details the results of 10 potato trials showing some response in tuber yield to sodium. Most of the trials showed a benefit from sodium (as sodium nitrate) when no potassium was applied. Early varieties gave no benefit when potassium was applied. The yield of maincrop varieties was increased by 9.6% where nil or a small amount of potassium was applied and 5.8% with normal or high levels of potassium. A further trial with sodium chloride indicated that sodium increased yields but chloride depressed yield. Chloride also depressed starch content.

Harmer & Benne (1945) found the response of potatoes to be similar to that of carrots and parsnips. Although potatoes may respond to sodium, use as salt is unlikely to be generally acceptable due to effect of chloride on starch content.

8.7 Leguminosae

Holt & Volk (1945) reported pot experiments with vetch, and Austrian winter peas. Sodium in the absence of potassium increased yields by only 17% and 19% respectively, a much smaller amount than for other crops. At high potassium levels sodium did not increase the yield of peas but increased the yield of vetches by 5.8%. Truog *et al.*, (1953) found that for lucerne, sodium increased yields at low potassium levels but not at high levels.

Though the information is limited it appears that legumes are generally unresponsive to sodium.

8.8 Cucurbitaceae

No experimental work on the use of salt or sodium on cucurbitaceae was found. On the basis of sodium uptake data, Harmer & Benne (1945) classify squash as unresponsive to sodium.

8.9 Compositae

Crops in this family include lettuce and chicory. Pereira & Westerman (1976) tested lettuce at a range of potassium and sodium levels. Sodium could partially replace potassium but was only half as efficient as potassium in increasing yield. Costigan & Mead (1987) determined the critical potassium concentration of lettuce seedlings in the presence and absence of sodium. The values were 10.6% K and 4.3% K. Thus, sodium can replace potassium to a limited extent but not in the same way as for cabbage where the critical potassium level was close to zero when sodium was present.

From this limited data it would appear that lettuce are relatively unresponsive to sodium.

Wehrmann & Hahndel (1984, 1985) found similar results for the effect of chloride on lettuce as for spinach. Chloride increased yield, a combination of nitrate plus chloride gave the maximum yield and reduced the nitrate content of the lettuce.

8.10 Liliaceae

The Liliaceae and the Graminae are monocotyledons. Vegetables in the Liliaceae are onions, leeks and asparagus. No recent experimental work on these crops has been found.

On the basis of the relative uptake of potassium and sodium, Harmer & Benne (1945) classify onions as unresponsive to sodium and asparagus as slightly responsive.

8.11 Graminae

The Gramineae include the cereal crops and maize. Of the small grains, oats have generally been found to be more responsive to sodium than wheat or barley (Dundas 1960). Truog et al., (1953) carried out trials with maize and found no effect from sodium application.

9. CIRCUMSTANCES WHERE SALT MAY NOT BE REQUIRED

Even for crops on which salt is recommended as a standard application, there are some situations where it is not thought to be necessary (Appendix 1). For carrots, it is only recommended for sandy soils. For celery, it is not recommended for peat and silt soils.

This is because the trials on carrots or sugar beet (Tinker, 1970) and carrots (Harrod, 1974) indicated less response on these soils, probably because of naturally higher sodium levels. However, few determinations of soil sodium levels are recorded in the literature. Costigan & Mead (1987) note 21 soils from commercial lettuce fields were all low in sodium. Fields near the coast are likely to have higher levels.

Allen & Cormack (1978) classified data from sugar beet trials with respect to soil type and soil sodium level. Organic soils often contained more than 100 mg/kg of available sodium and did not respond to salt. Clay loams contained 20-100 mg/kg sodium and responses were small. Sandy soils and light loams contained least sodium (5-20 mg/kg) and gave good response to salt. Draycott & Durrant (1981) concluded that sugar beet growing on peats and peaty mineral soils did not need salt, and seldom needed potassium. Sandy soils required 375 kg/ha salt but the less responsive clays and silts only required 210 kg/ha salt.

10. THE EVIDENCE FOR CURRENT RECOMMENDATIONS FOR SALT

Appendix 1 gives the current ADAS recommendations for salt. The only vegetable crops included are carrots and celery.

The carrot recommendations are based on the work of Harrod et al., (1974) and Harrod (1974). As there were 9 trials on sandy soils with consistent response to salt, there is good evidence for the use of salt on carrots. The response on peaty soils was lower hence the reason salt is not recommended on these soils. No test of the effect of salt on the quality of carrots was carried out which may have shown benefits. Neither were soil tests for sodium used to explain the variation in response.

No published experimental work on the use of salt on outdoor celery has been found. The current recommendations date back to the recommendations published by MAFF in 1983, although salt has been recommended for celery since recommendations were published in 1959. The soils on which it has been recommended have changed, possibly to align the salt recommendation to that for sugar beet. The sugar beet recommendations were revised in 1979 to exclude the use of salt on fen peats and fen silts following the publication of the experimental work on peat soils by Tinker (1970).

11. THE EVIDENCE FOR CONSIDERING SALT FOR CROPS FOR WHICH IT IS NOT CURRENTLY RECOMMENDED.

Table 3 summarises the main information reviewed earlier on the response of vegetables to salt or sodium. When considering these results more weight is given to field trials, particularly those with a range of sites on UK trials, than to pot or glasshouse studies. These results need combining with information on botanical similarities between crops, although as noted earlier botanical similarity is not an adequate basis for making recommendations.

Table 3 Summary of Crop Response to Sodium

Crop	Yield increase with ample K	Yield increase at low K	
Sugar beet	4%	12%	Tinker (1965)
Beetroot	40%		Truog *et al.*, (1953)
Spinach	23%		Dundas (1964b)
Cabbage	2-11%		Dundas (1965)
	11-28%		"
	10%		Nicholson & Hooper (1957)
Kale	7%	5%	Hemingway (1960b)
Turnip	3%	132%	Holt & Volk (1945)
	10%	9%	Hemingway (1960a)
	14%	67%	Lehr (1951)
Swede	14%	40%	Truog *et al.*, (1953)
Carrot	4%	44%	Hunter (1968a)
	9%	15%	Harrod *et al.*, (1974)
	4%	-9%	Harrod (1974) (Peats)
Celery	17-36%		Dundas (1964c)
	21-61%		"
	55%		Truog *et al.*, (1953)
	6%		Marks (1990)
Parsnips	?		Harmer & Benne (1945)
Potato	5.8%	9.6%	Lehr (1953)
	0		Truog *et al.*, (1953)
Peas	0	19	Holt & Volk (1945)

Crop	Yield increase with ample K	Yield increase at low K	
Lettuce	?		Costigan & Meas (1987)
Sweet Corn	0		Truog *et al.*, (1953)

Harmer and Benne (1945) produced a tentative classification for crop responsiveness to sodium based on experimental trials and sodium uptake data. This classification has been widely accepted by subsequent authors although the position of some crops within the classification has been changed as new evidence become available. The original classification and comments are in Table 4.

Table 4. Effect of sodium applied as a nutrient on several crops (Harmer & Benne 1945)

NUMBER	DEGREE OF BENEFIT IN DEFICIENCY OF POTASH		DEGREE OF BENEFIT IN SUFFICIENCY OF POTASH	
	1. None to very slight	2. Slight to medium	3. Slight to medium	4. Large
1	Buckwheat	Asparagus	Cabbage	Celery
2	Corn	Barley	Celeriac	Mangel
3	Lettuce	Broccoli	Horse-radish	Sugar beet
4	Onion	Brussels sprouts	Kale	Swiss chard
5	Parsley	Caraway	Kohlrabi	Table beet
6	Parsnip	Carrot	Mustard	Turnip
7	Peppermint	Chicory	Radish	
8	Potato	Cotton	Rape	
9	Rye	Flax		
10	Soyabean	Millet		
11	Spinach	Oat		
12	Squash	Pea		
13	Strawberry	Rutabaga		
14	Sunflowers	Tomato		
15	White bean	Vetch		
16		Wheat		

Column 4 is a list of six crops which have a high sodium requirement and which, incidentally, are among the most susceptible to boron deficiency. Five of these crops are classed as halophytes, (grow on salty soils) but celery appears not to have been placed in that group. With the exception of celeriac, all of the crops in column 3 likewise are halophytes. Two of the 14 belong to the parsley (Umbelliferae) family, four to the beet (Beta), and eight to the mustard (Cruciferae) family.

This table has what appears to be anomalies, for example spinach in group 1 and turnip in group 4.

Lehr (1953) produced a similar classification of 4 groups A, B, C, D. A corresponds to group 4 of Harmer & Benne (1945). A smaller range of crops is included. Some of the apparent anomalies are spinach classified as very responsive and turnip as less responsive. Potatoes and turnips are classed as intermediate between 2 and 3. Swedes still remain in group 4, although one would expect them to be similar to turnips.

From the evidence reviewed in previous sections a revised tentative classification can be drawn up for UK vegetable crops.

Table 5 Likely responsiveness of crops to salt

Crops for which salt application is known to be worthwhile under UK conditions (with certain qualifications)

Sugar beet
Carrots

Crops for which salt application would probably be beneficial

Celery
Beetroot
Spinach
Cabbage
Kale
Turnips

Crops for which salt may be beneficial

- Parsnip
- Swede
- Potato (sodium not salt)

Crops for which salt is unlikely to be beneficial

- Peas
- Lettuce (except perhaps for quality)
- Sweet corn

Crops for which there is little information

- Beans
- Onion
- Leeks
- Courgette, Marrow
- Tomato
- Cauliflower
- Chicory
- Brussels sprouts
- Calabrese
- Asparagus
- Radish

Sugar beet has again been included as the standard against which to judge the vegetable crops because of the wealth of information or sugar beet response to salt.

From the experimental evidence, and the botanical similarities, it would seem probable that carrots, celery, beetroot, spinach, cabbage, kale and turnips are crops likely to benefit from salt. From this list there is excellent evidence for carrots, good evidence for kale, turnips and celery, but inconclusive evidence for the other crops. Beetroot and spinach are included because of the evidence and their close similarity to sugar beet. Other crops which may respond are parsnip, potato and swedes.

There are some important crops for which there is little information which because of their botanical relationship to responsive species may well respond to salt, for example brussels sprouts, calabrese, cauliflower. Before the use of salt can be confidently recommended for crops other than carrots and celery, some field trials would be necessary to confirm that the benefits obtained by research workers in other countries can be obtained in the UK. Trials are also needed on the crops for which there is little information.

12. BENEFITS FROM USING SALT - EXISTING RECOMMENDATIONS

The yield benefit for carrots is 9% (Harrod et al., 1974). A conservative estimate of the benefit for celery would be 10%. Using gross output data for these crops (Anon., 1990) the benefit per hectare can be calculated. The cost of salt at 400 kg/ha is about £24/ha. On carrots, there is a possible saving of 60 kg/ha potash worth £11. The net cost of salt is £13/ha for carrots and £24/ha for celery.

The net benefit per hectare is £295 for carrots and £1411 for celery.

The net benefit calculations are given in Table 6.

Table 6. Estimated value of yield increase from applying salt

	Gross Output (£ per hectare)	Yield increase (%)	Cost of salt (£)	Net Benefit (£/ha)
Carrots	3420	9	13	295
Celery	14350	10	24	1411
Beetroot	1890	5	24	70
Spinach	4800	5	24	216
Cabbage	6500	5	24	301
Kale	4770	5	24	214
Turnip	3110	5	24	131

13. POSSIBLE BENEFITS FROM EXTENDING THE USE OF SALT TO OTHER CROPS

For these crops, a conservative estimate of likely yield increase has been taken as 5%. Using gross output data, the benefits, have been calculated and are also given in Table 4.

To obtain the total benefit on a national basis the benefit per hectare is multiplied by the area. An stimate was made of the area of carrots, celery, beetroot and spinach grown onpeaty soils as there is no benefit from salt on peaty soils. Table 7 shows the estiamted national benefit.

Table 7. Potential benefit from salt on a national basis

Crop	Soil	Hectares UK 1989	Benefit £ per hectare	Total Benefit £K
Carrots	All	14900		
	Peats	4900	0	0
	Mineral	10000	295	2950
Celery	All	640		
	Peats	540	0	
	Mineral	100	1411	141
Total				£3,091
Beetroot	All	2170		
	Peats	1570	0	0
	Mineral	600	70	42
Spinach	All	248*		
	Peats	48	0	0
	Mineral	200	216	43
Cabbage		15500	301	4666
Kale		155*	214	33
Turnips		809*	131	106
Total			Total	£4,890

*England and Wales

Thus, the potential benefit for crops for which there are existing recommendations is around £3M and for extending the recommendations to other likely crops is another £5M.

14. POSSIBLE BENEFITS IN IMPROVED QUALITY OF PRODUCE

Where research workers have conducted taste tests, they have reported that for carrots and turnips, sodium application gives a sweeter milder taste. Celery is reported to be less stringy, and crisper. Turnips are reported to be less woody.

These improvements in quality may apply to all crops and the value of improved quality alone could make the use of salt worthwhile. Chloride has been shown to reduce the nitrate content of lettuce and spinach without reducing yield. This factor could increase the value of crops with a tendency to high nitrate levels.

15. ALTERNATIVES TO SALT

Most of the benefits of salt are assumed to be due to its sodium content, as ample chloride is usually applied as potassium chloride. Other forms of sodium, for example sodium nitrate, may be equally beneficial.

Sodium and potassium chlorides occur as the mineral sylvinite at Cleveland and are extracted and sold in this form. 500 kg of sylvinite will supply potassium equivalent to 156 kg of K_2O and sodium equivalent to 212 kg Nace. This mineral has proved a convenient way of applying potassium and sodium to sugar beet. Kainit has been used for sugar beet and other crops for many years. It contains about 12% K_2O 20% Na and 3% Mg.

Nitrate of soda contains 16% N and 26% Na and can supply sodium when used as a nitrogen fertiliser.

16. ADVERSE EFFECTS OF SALT

The adverse effects of salt as a foliar spray are well known as scorch effects on vegetation in coastal areas. Salt is particularly damaging as it has a high osmotic pressure. The same osmotic effect applies when salt is applied to the soil. By raising the osmotic pressure of the soil solution, salt makes it more difficult for plants or seeds to extract water from the soil. Chloride also has specific adverse effects on plants at high concentrations. This specific effect varies with species. To reduce the osmotic effect it is recommended that when salt is applied to crops it must be worked deeply into the soil before drilling or be ploughed in (Anon., 1987).

Sodium has an adverse effect on soil structure and when applied in very large amounts, such as on land flooded by seawater, it can have very deleterious effects. However, at the rates applied to crops effects on soil structure are rarely observed (Dundas 1962), (Draycott & Bugg, 1982).

17. USE OF SALT AS A HERBICIDE

The specific chloride effects of salt allow it to be used as a herbicide. No reports of experimental work on the subject have been found. A long established practice is to use kainit on pastures to kill nettles and supply potassium and sodium. The possibility of using salt as a weedkiller was noted by Selman (1938). Salt is a very effective weedkiller on asparagus beds (Davies, 1990).

The action of salt depends upon its effect on osmotic pressure of the soil solution or its scorching effect if applied as a foliar spray. The chloride in salt also has a more specific effect. Williams (1972) classifies crops according to their sensitivity to salt (Table 8).

Table 8. Crop tolerance related to conductivity and chloride concentration

Crop tolerance group	Conductivity of saturation extract (mmhos/cm) (upper limit)	Chloride conc'n in soil moisture (mg Cl/litre) at field capacity (upper limit)	Fruit	Vegetables	Agricultural crops	Flowers
A Very sensitive	3·0	350	Strawberries Blackberries Gooseberries Plums	French beans Peas		Azaleas Fresias Hydrangea
B Moderately sensitive	5·0	750	Apples, Pears Red Currants Raspberries	Radish Celery Lettuce Onion	Clovers Maize M. Foxtail Beans Cocksfoot	Asters Gladioli Roses Tulips Narcissi
C Slightly sensitive	8·0	1450	Blackcurrants Vines	Carrots Cauliflower Broccoli Potatoes Cabbage	Wheat Oats Rye Ryegrass Lucerne Fescue	Carnation Chrysanths Stocks
D Least sensitive	12·0	2500		Asparagus Spinach Red Beet	Kale Rape Barley Sugar Beet Mangolds	

From: Williams, 1972

This table is interesting in that the sensitivity to salt is in inverse order to the benefit from salt as a fertiliser. Using botanical families the sensitivity is as follows.

Very sensitive	Leguminosae
Moderately sensitive	Compositae, Liliaceae
Slightly sensitive	Solanaceae
Least sensitive	Chenopodiaceae

This classification has some inconsistencies; as some Cruciferae appear in both the least sensitive and slightly sensitive groups and Umbelliferae in both slightly sensitive and moderately sensitive. Gramineae span three tolerance groups.

The table does show that the crops for which salt would be most useful as a herbicide are beetroot, spinach, asparagus and kale. Other possible crops are carrots, cauliflower, broccoli and cabbage.

When salt is applied to the soil, the concentration in the soil solution depends on the moisture content of the soil and the depth of incorporation. The moisture contents of the soil will vary widely but, assuming the soil is at field capacity, the moisture content will be 30% for a sandy loam, 40% for a silt loam and 50% for a silty clay.

Assuming the salt is being used to control seedling weeds with a target chloride concentration of 1000 mg/l of soil solution in the 0-20 cm zone, the amount required is:-

99 kg/ha for a sandy loam
132 kg/ha for a silt loam
165 kg/ha for a silty clay

The maximum chloride concentration in the soil solution at permanent wilting point would be

2310 mg/litre in as a sandy loam
2670 mg/litre in as a silt loam
1790 mg/litre in as a silty clay

This is near or slightly above the tolerance limit for the least sensitive crops but should be safe as the soil is unlikely to reach permanent wilting point early in the season.

Thus a surface application of salt adjusted according to soil texture but in the range 100-165 kg/ha would probably control weeds of the Leguminosae and Compositae families in crops of beetroot, spinach, asparagus and kale. Rainfall after application would leach out the salt and reduce its effectiveness. Field trials are required to test rates and effectiveness of salt as a herbicide.

18. INTERACTIONS OF SALT AS A FERTILISER AND AS A HERBICIDE

The use of salt as a herbicide is most likely to be on those crops which benefit from its use as a fertiliser. The rate suggested as a herbicide is 100-165 kg/ha, whereas the fertiliser rate is normally 400 kg/ha. When used as a fertiliser salt is normally applied well before the crop is sown or planted and incorporated thoroughly into the topsoil to avoid damage to the crop. An application of 100-165 kg/ha would have some fertilising effect but not as much as the normal rate. The only option where salt is to have a dual effect would be to incorporate part of the salt before planting, possibly as a mixed fertiliser (Sylvinite, Kainit or blend) and apply the remainder as a top dressing to control weeds. Dundas (1962) gives examples of the use of nitrate of soda as a fertiliser and herbicide in sugar beet. The rate recommended is 312-375 kg/ha in 730-1120 litres of water plus a spreader.

19. CURRENT USE OF SALT IN ENGLAND, WALES AND SCOTLAND

The annual Survey of Fertiliser Practice (Chalmers et al., 1990) collects information on the use of salt as a fertiliser. As salt is only used on relatively few fields, the data have been averaged for the years 1985-1989 (Table 9).

Table 9. Use of salt on crops - England and Wales 1985-89

Crop	England and Wales % of crop on which salt used	Average rate of salt (kg/ha)
Sugar beet	54	402
Early potato	1	321
Brussels sprouts	1	185
Cabbage	2	228
Kale	1	383
Swedes	1	370
Onions	1	73

The Scottish Survey did not record any use of salt. These figures are surprising. Some of the unexpected use for crops such as onions and early potatoes may be due to the use of potash fertilisers containing salt rather than the use of salt itself.

The use of salt on sugar beet is disappointing when salt is recommended as standard for all crops except those grown on organic, peaty and fen silt soils. This low use of salt may be an indication of the undervaluing of salt by farmers and growers.

No information has been collected on carrot or celery crops in recent surveys and a separate survey on the use of salt on vegetables and growers attitudes to its use would be worthwhile.

20. CONCLUSIONS

Sodium is not an essential nutrient for plants although chlorine is. The chlorine requirement is normally supplied in adequate quantities from rainfall and from potassium chloride fertiliser.

Sodium is known to have beneficial effects on some crops. The crops which benefit can be partly but not entirely distinguished on the basis of botanical similarities and measurement of sodium uptake potential. For many crops the beneficial effects require to be tested under UK field conditions to decide for which crops salt or sodium may be of value as a fertiliser.

There is very good experimental evidence from UK trials that salt is beneficial for carrots and for this crop no further trials are needed. There is good evidence that salt is probably beneficial for celery, beetroot, spinach, kale, turnips and cabbage but further trials are needed to measure the economic benefit. In addition to yield effects, salt may improve taste, eating quality and reduce nitrate levels.

The estimated benefit from using salt is £3M on carrots and celery and another £5M on the other crops for which it is not currently used. The use of salt on these other crops could not be recommended with confidence without some field trials.

The use of salt on the crops for which it is recommended may be less than is justified. A survey of the use of salt by growers would be worthwhile. This survey should include the use of salt as a herbicide. There appears to be no published work on this although salt is known to be used in this way. Calculations indicate that for some crops, generally the same crops for which salt is beneficial as a fertiliser, salt could have value as a herbicide. Before recommendations can be made the application rates and effectiveness would need testing in the field.

As the crops on which salt is likely to be useful as a herbicide are generally the same ones for which it is beneficial as a fertiliser, then it could serve a dual purpose in some situations.

Most of the evidence for the use of salt comes from scientific journals of some time ago. There is a paucity of recent information on the use of salt. This may be due to the fact that field trials on which fertiliser recommendations are based are not written up for publication. To save duplication of R & D and to obtain information on what is considered practical in other countries, a databank of fertiliser recommendations for vegetables grown in temperate climates would be extremely valuable. This would indicate what fertiliser applications are considered practical and give valuable indications as to where UK practice is different. It should also provide indication as to the basic R & D work on which recommendations have been based, but which have not been published. This would reduce the duplication of R & D.

21. RECOMMENDATIONS FOR FURTHER INVESTIGATIONS

a. Field Trials

In the UK, the main R & D on the use of salt or sodium fertiliser for vegetables has been limited to carrots, kale, turnips and cabbage. It seems likely that celery, beetroot, spinach may also benefit from sodium or salt. The initial need for R & D is to test all of these crops except carrots for responsiveness to sodium. Another crop that should be tested is lettuce, to measure the effect of salt on reducing nitrate content. The crops could be grown successively at one or two sites or on separate experiments. The treatments would need to include a range of potassium levels, a range of salt levels and comparisons of sodium nitrate and ammonium nitrate. In addition to yield, quality tests including taste and nitrate content should be measured. Sodium levels in the soil and crop should be measured, in addition to the usual soil and crop analyses.

A separate series of trials on growers holdings should be set up to test the value of salt on these crops. These trials would require only a nil, medium and high rates of salt replicated a few times. Measurements would be yield, grade and quality assessments, soil and crop analyses. These trials would be simple to conduct, only requiring scientific input at the beginning and at harvest supplemented by observations from the grower. They would enable the value of salt to be tested in a wide range of situations at fairly low cost.

Once the crops most likely to respond have been tested, then other crops for which salt may be beneficial could be tested; these would include parsnip, swede, cauliflower, calabrese and brussels sprouts.

b. <u>Databank of Fertiliser Recommendations</u>

This review has highlighted the paucity of up-to-date information on the fertiliser requirements of vegetable crops. To save duplicating R & D and to stimulate new thinking it would be valuable to set up a simple database of fertiliser requirements of vegetable crops in temperate climates. Many of the vegetable crops grown in the UK are also grown in similar climates in other parts of the world, principally Europe, the USA, Canada and New Zealand.

c. Survey on the Use of Salt

Because the Survey of Fertiliser Practice covers only a limited selection of vegetable growers a survey of the use of salt, on vegetables and attitudes to the use by growers, would provide basic data on which to build advice about the use of salt. Such a survey could be carried out by post or by advisers when visiting growers for other purposes.

d. Use of Salt as a Herbicide

Information on the use of salt as a herbicide should be sought from growers known to use salt in this way. Simple observation studies on the use of salt as a herbicide should be set up.

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Appendix 1

1. CURRENT ADAS RECOMMENDATIONS FOR THE USE OF SALT

MAFF Reference Book 209
Fertiliser recommendations HMSO 1988

Carrots on Sands and Light Loams

400 kg/ha salt should be applied and the potash (K_2O) reduced by 60 kg/ha. Salt must be worked deeply into the soil before drilling or be ploughed in.

Celery

400 kg/ha salt recommended for all soils except fen peats and fen silts. This is in addition to the potash application. The salt should be ploughed in or worked into the soil at least one month before planting out or direct drilling.

Salt is also recommended for sugar beet (400 kg/ha) except for organic, peaty and fen silt soils. If not used an extra 100 kg/ha potash is recommended. Salt is recommended for mangels and fodder beet on the same basis as for sugar beet.